FUEL CELLS

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Fuel cells are electrochemical devices which oxidize fuel and convert the heat of combustion into electrical energy. The operating process is opposite to that of electrolysis and uses hydrogen and oxygen as a fuel. Electrical energy is produced when hydrogen is oxidized in water. Inert materials (nickel, graphite) are used to produce porous electrodes saturated continuously with oxygen and hydrogen. The electrodes are not used up in operation. Oxygen (O) molecules are adsorbed by the surface of the positive electrode. This layer is more active than molecular hydrogen and reacts with the water in the elctrolyte (35-40% KOH in solution) to give two (OH-) ions. The latter have a negative charge and when formed, take two electrons from the electrode, making it positive. The (OH-) ions react with hydrogen adsorbed by the surface of the other electrode to form water and two electrodes to charge that electrode negatively. A current will flow in a loaded circuit connected to the electrodes. The reaction takes place in the following manner:

  a. on the oxygen (positive) electrode

$$1/2 \ O_2 = O; \quad O + H_2O + 2e- = 2OH-;$$
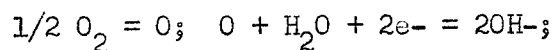
  b. on the hydrogen (negative) electrode

$$H_2 = 2H; \quad 2H + 2OH- = 2H_2O + 2e-.$$
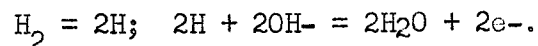
In England the HYDROX Fuel Cell Battery has been developed on this principle after many years of effort. Its capacity is 2.5 kwt at 32 volts or 5 kwt at 24 volts. When not loaded, the battery produces 42 volts. The battery has 40 cells, each of which consists of two electrodes in the form of 25 cm diameter discs of porous agglomerated nickel (Figure 1). Between the discs there is a 2 mm layer of 40% KOH in solution. The electrode surfaces touched by the electrolyte have a very fine layer of 16 micron diameter pores. The remaining pores have a diameter of 30-40 microns.

To prevent corrosion, the oxygen electrode is surfaced with

lithium and oxidized. The outer surfaces of the discs are supplied with oxygen and hydrogen from tanks-2. Both gasses attempt to diffuse through the pores; this also prevents the electrolyte from seeping back from the other side.

The electrolyte surface tension prevents the diffusing gas from passing through the smaller pores. The electrode construction provides 40 sq m of surface contact between the gas and the electrolyte. Thus, the cell produces a large current (to 200 amp and higher at 0.6 volts). The current-to-area ratio reaches 500-600 ma/sq cm. The cell operates at 65% efficiency. The cell operates at 200 degrees Centigrade gas temperature and at a pressure approximating 60 atmospheres. Heat for starting is supplied by electrical preheaters-3. The high temperature is maintained as a product of the reaction. Sometimes, the cells must even be cooled.

Pressure regulation is automatically controlled. The difference between gas and electrolyte pressure is several centimeters on a water column. Oxygen pressure is constant, while hydrogen pressure is regulated in relation to the first by an accurate differential pressure gauge-5. Water formed on the negative electrode during the reaction, turns to steam and is drawn off into condenser-6.

The fuel cell battery described is 75 cm long and 30 cm in diameter. Each cell is about 13 mm thick. The power-to-cubic volume ratio is approximately 300 kw for each cubic meter of internal cell capacity or a power-to-area ratio of 22 volts to 1 kg weight. To produce 1 kw/hr requires 0.54 cubic meters hydrogen and 0.27 cubic meters oxygen at normal pressure and temperature.

The best method for employment of such cells follows: During the hours of minimum energy requirements, alternating current from the bus bar is fed through the rectifier into the electrolyzer where water is separated into hydrogen and oxygen which, in turn, are collected in tanks. During peak periods the gases are fed into the fuel cells, the electrical energy produced is fed through a converter into the station bus bars. When the electrolyzer is 75% efficient and the fuel cell - 65% efficient, overall efficiency may equal 45%.

There is major industrial interest in fuel cells which use solid fuels, coal--for example, which is subjected to this gasification. This method is being studied by the University of Amsterdam in Holland and the Consolidated Coal Company in the USA. They have succeeded in creating fuel cells that operate at a temperature of 500 - 850 degrees Centigrade and at atmospheric pressure. In these cells Oxidation takes place with air and gas received from the coal. The cell (Figure 2) consists of two flanges (hollow cup-shaped bodies in this case) - 1 and the electrolyte carrying matrix-2. The latter takes the form of a porous disc of a high melting point magnesium oxide. This salt serves as the electrolyte. Porous electrodes -3 are adjacent to both sides of the matrix. The upper electrode is of a powdered semi-conducting nickel oxide or a

silver wire mesh. The lower electrode is of powdered nickel or iron. Both electrodes have current collectors, consisting of springs-4 and shafts-5. The "flanges" are held together by insulated bolts--6. Gaskets-7 and 8 serve to seal the cell.

Air with a small additional amount of CO_2 continuously supplied by pipe-9 and drawn off by pipe-10. Fuel is continuously supplied and drawn off by the lower pipes--11 and 12. Both streams should meet. The best fuel is a specific mixture of CO and CO_2. The greater the Co/CO_2 ratio and the higher the mixture temperature, the greater the no-load voltage and voltage under load (Figure 3).

Estimated voltage can be determined by the Nernst formula. In a no-load state, voltage is a magnitude on the order of 0.8 volts. Under a large loading, this voltage may decrease to half this value or even less. The wattage output per sq cm of electrode surface area influences cell economy. The designer states that when the current-to-area ratio = 33 ma/sq cm exists, it is practical to obtain an 0.75 volt output. Theoretically this voltage may be obtained when = 22 ma/sq cm. By experiment it was found that the cell operated without polarization of the air electrode when the current-to-area ratio was =125 ma/sq cm. The voltage drop always equals the current multiplied by internal resistance measured by an alternating current bridge. Experimental data states that the cells should last for more than six months.

The efficiency of a system consisting of fuel cells connected in series, and gas generators, may reach 75%. If the coal is completely used up and steam is produced from its gasification, the efficiency will be more than 75%. This leads to the conclusion that future installations may be competitive with steam power plants and even atomic power plants, especially when coal fields are close at hand.

Electrical Times, No. 3531, 1959,

Electrical Journal, No. 9, 1959,

Mechanical Engineering, No. 3, 1959,

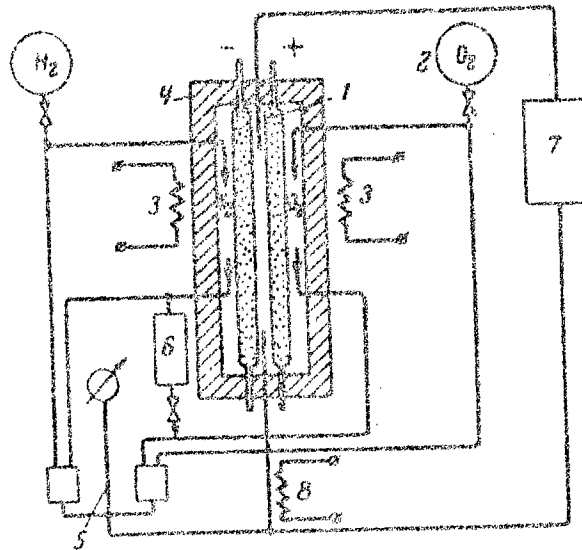Electrical World, No. 12, 1959.

Figure 1. Oxygen-hydrogen fuel cell.

1. Electrode
2. Tank
3. Preheater for gas
4. Fuel cell body
5. Differential pressure gauge
6. Condenser
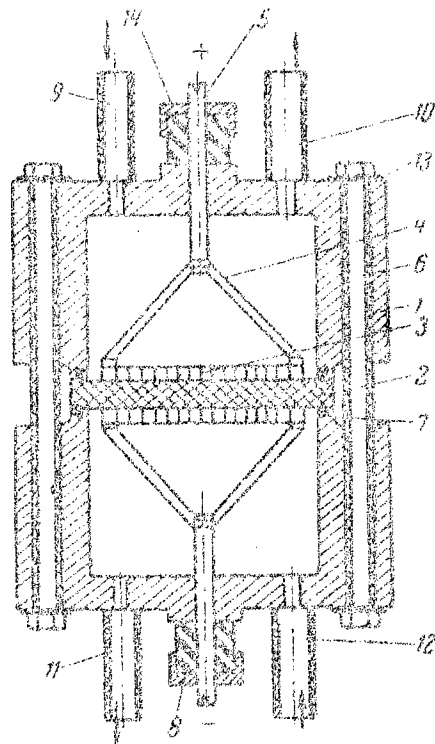7. Electrolyte tank
8. Preheater for electrolyte

Figure 2. Construction of a gas fuel cell.

1. "Flange"
2. Matrix
3. Electrode
4. Flat spring
5. Current collector shaft
6. Bolt
7. Gasket
8. Gasket
9. Air inlet pipe
10. Air outlet pipe
11. Gas inlet pipe
12. Gas outlet pipe
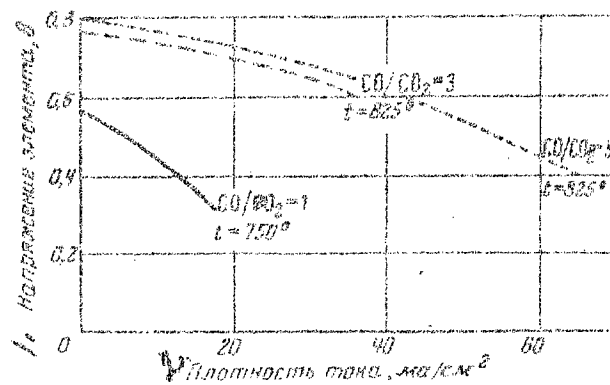13. Insulating washer
14. Pressure cap

Рис. 3. Кривые зависимости напряжения элемента от
плотности тока.

Figure 3.   Curves based on cell voltage and
current-to-area ratio.

1.   Cell voltage v.
2.   Current-to-area ratio, ma/sq cm

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